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Seismic Performance of Soft Storey RC Building With and Without Floating Column

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ABSTRACT: Due to rapid urbanization, column free spaces and soft storey construction are needed in the multistorey building in the cities due to space constraints, rapid population growth as well as different types of functional uses. The term floating column refers to a vertical component or element of the building rest at its lower level on a beam that is a horizontal component. The beam than transfer the coming load to another column underneath it. A soft storey is a building level having lower capacity to resist the lateral load compared to the storey above it. Due to the soft storey, a slow collapse of such a building in a major earthquake becomes unavoidable as a result of these features, which decreases the stiffness of the lateral load resisting system. Using ETABS, the seismic performance of soft storey RC buildings with and without floating columns is studied. Various seismic parameters, including storey displacement, storey drift, storey shear, stiffness, torsion, and modal shape, are evaluated and compared to predict the effectiveness of these structures in zone V. G+9 building with soft storey in the ground and first floors with and without floating columns is considered both effective and efficient. Based on the analysis and results obtained, it is observed that displacement of the storey, drift, torsion, time period is more and storey shear, stiffness is less for the floating column building in the comparison of without floating column building.

KEYWORDS: Floating column, Soft storey, response spectrum analysis, seismic parameters, Etabs.

I. INTRODUCTION

Nowadays, the population is growing rapidly and all of them require different type of facility such as parking, meeting hall, small open spaces for different functional uses in a limited area. Due to the limited area of urbanization, horizontal expansion is not possible so vertical expansion is done having all such facilities. In the cities, buildings are generally provided floating column and soft storey in the ground or 1st floor and it is unavoidable. Providing such floating column and soft storey in the building are too dangerous in the highly seismic zones. In this paper, G+9 building having Ground and 1st floor soft storey with and without floating column is analysed and different seismic parameter such as displacement of the story, storey drift, stiffness, storey shear, torsion and mode shape are compared for both the model by Etabs.

Floating Column

Generally, column a vertical member rests on the foundation. But in the floating column building, it does not rest on the foundation rather it rests on the beam, a horizontal element. The load concentrated to the beam is transferred to the adjacent column below it.

Soft storey

A soft storey building is provided in its ground floor or any other floor with large unobstructed commercial space for parking or other functional uses. Such storey is not provided with infill wall or shear wall. In some building, shear wall may be provided for the stability of building or to resist the seismic effects. A soft storey undergoes huge destruction due to the earthquake force.

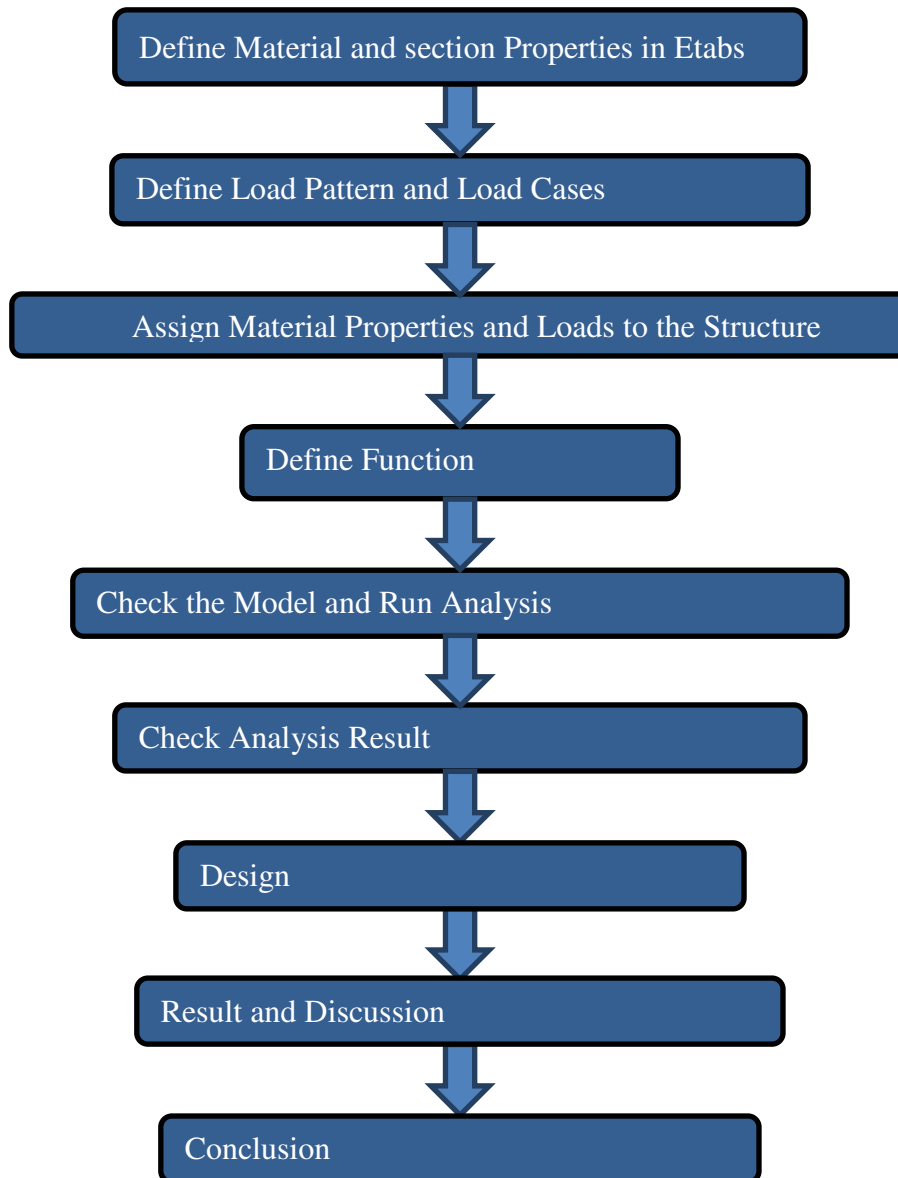
II. OBJECTIVE OF THE STUDY

- To study the Seismic performance of soft storey RC building with and without floating column using ETABS by Response spectrum analysis method.
- To Evaluate different factors like displacement of the story, storey drift, Storey shear, storey stiffness, torsion and modal shape.



•To Compare and predict the effectiveness of a soft storey RC building with and without floating columns in seismic zone 5.

III. METHODOLOGY



IV. MODELLING

G+9 building with soft storey in ground and 1st floor and with and without floating column located in seismic zone v according to IS code 1893-2016 are taken for investigation.

Model description

- Building dimension: 25m x 16m
- Height of the floor: GF to 1st floor 4m,
1st to 8th 3.3m and
9th & 10th floor 3m
- Column size: 0.65m X 0.65m,
0.35mX 0.45m
- Beam size: 0.23m X 0.425m,
0.35mX0.60m

- Slab thickness: 0.125m
- Concrete Grade: M20,
M25,
M30
- Steel Grade: FE 500
- Density of masonry wall: 20KN/m³
- Seismic zone: V
- Importance factor: 1.2
- Building frame: Special RC moment resisting frame (SMRF)
- Dead load: Program calculated
- Live load: 3 KN/m²
- Floor load: 1.5 KN/m²
- Wall Load: 10"- 10.7 KN/m² and 5"- 6KN/m²

Structural Plans

Model 1: G+9 storey building with ground floor and 1st as a soft storey and F- Grid column as a floating column.

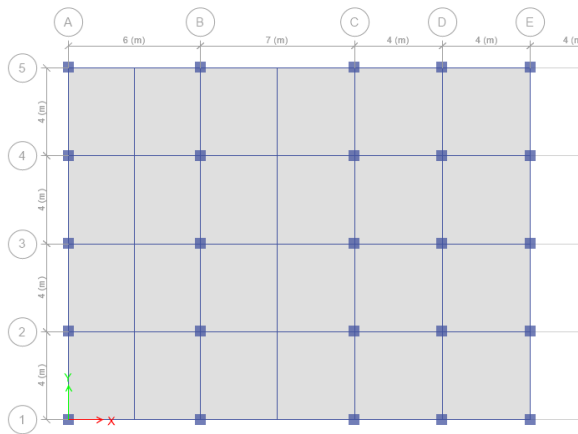


Fig. 3D view of Floating column Building

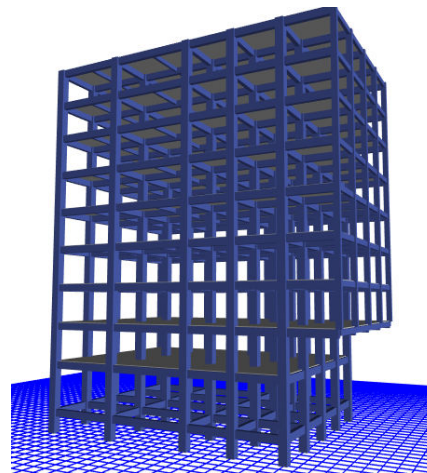


Fig. Plan of 1st storey of Floating column building

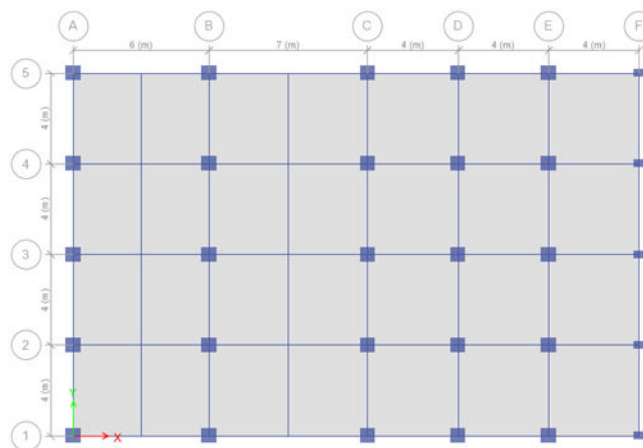


Fig. Plan of 3rd to top storey of Floating Column Building

Model 2: G+ 9 storey Regular building

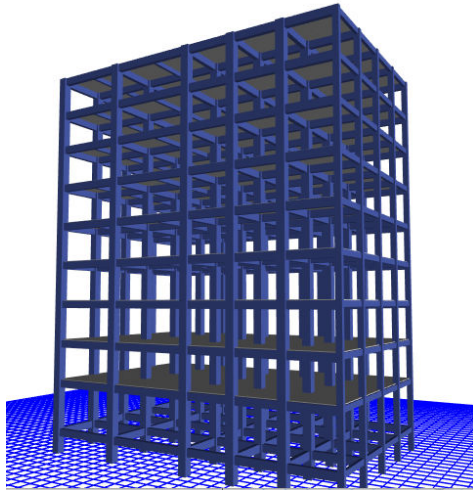


Fig. 3D view of Regular Building

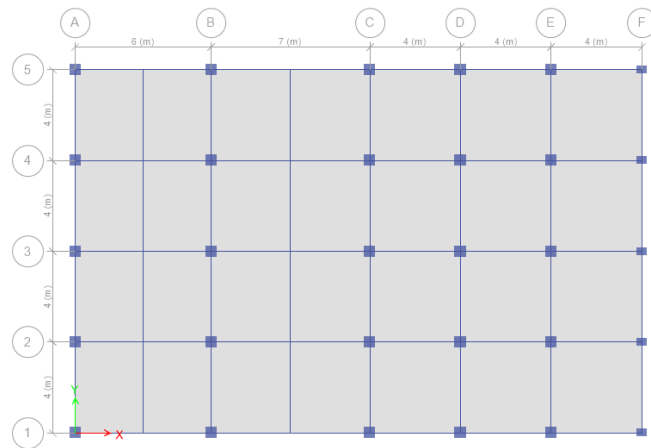


Fig. Plan view of Regular Building

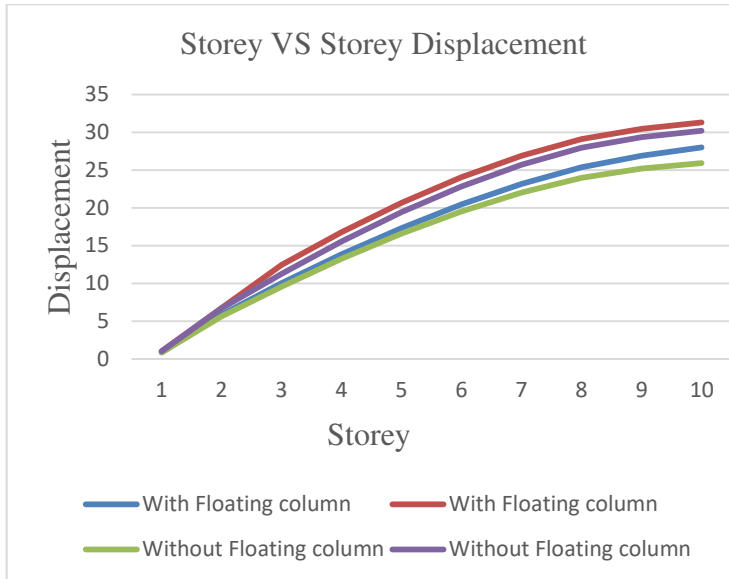
Load Combination

Load combination No.	Load Combination detail
1	1.5 (DL+ FF+WL)
2	1.5 (DL+LL+ FF+WL)
3	1.2(DL+LL+ FF+ WL + EQ _x)
4	1.2(DL+LL+ FF+WL-EQ _x)
5	1.2(DL+LL+ FF+WL +EQ _y)
6	1.2(DL+LL+ FF+WL-EQ _y)
7	1.5(DL+ FF +WL +EQ _x)
8	1.5(DL+ FF+WL-EQ _x)
9	1.5(DL+ FF +WL +EQ _x)
10	1.5(DL+ FF+WL-EQ _x)
11	0.9(DL+ FF+WL) + 1.5EQ _x
12	0.9(DL+ FF+WL)- 1.5EQ _x
13	0.9(DL+ FF+WL) + 1.5EQ _y
14	0.9(DL+ FF+WL)- 1.5EQ _y
15	1.2(DL+LL+ FF +WL +RS _x)
16	1.2(DL+LL+ FF +WL +RS _y)
17	1.5(DL+LL+ FF +WL +RS _x)
18	1.5(DL+LL+ FF +WL +RS _y)
19	0.9(DL+ FF+WL) + 1.5RS _x
20	0.9(DL+ FF+WL) + 1.5RS _y

V. EXPERIMENTAL RESULTS

5.1. Storey displacement

The lateral displacement of the story with respect to the base is known as storey displacement. The excessive lateral movement of the building can be controlled by the lateral force-resisting system. The result shown for earthquake load cases response spectrum in X and Y direction. The displacement of the story is within the permitted range $H/250 = 31800/250 = 127.2\text{mm}$ according to IS code 1893-2016 clause 7.11.



Storey	With Floating column		Without Floating column	
	RSx (mm)	RSy (mm)	RSx (mm)	RSy (mm)
1	0.904	1.049	0.87	1.029
2	5.856	6.763	5.639	6.687
3	10.04	12.47	9.586	11.29
4	13.86	16.8	13.27	15.56
5	17.34	20.67	16.61	19.43
6	20.46	24.05	19.55	22.84
7	23.16	26.89	22.04	25.71
8	25.39	29.11	23.99	27.96
9	26.9	30.47	25.2	29.34
10	27.98	31.32	25.94	30.2

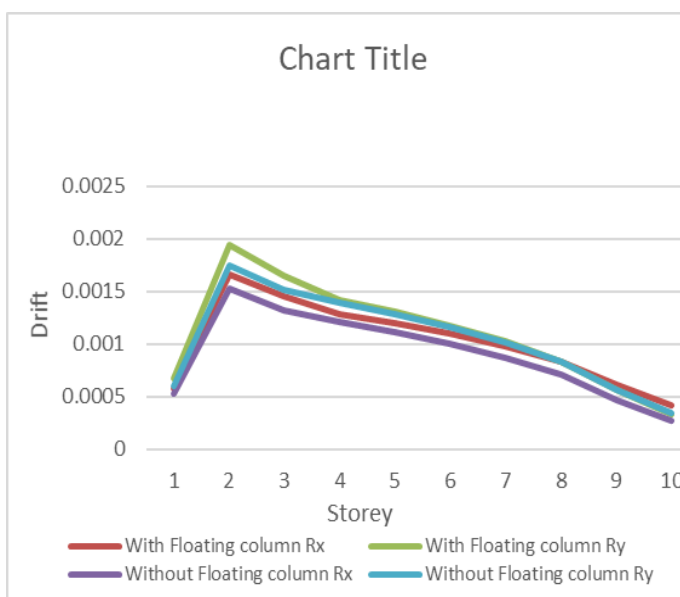
Fig. 5.1. Storey Displacement

Table 5.1. Storey displacement observation

- As per the above graph it is observed that displacement of the storey increases with the increase in storey height in X and Y direction for earthquake load cases RSx and RSy.
- Maximum displacement of the storey of building with floating column is 7.8% and 3.7% more as compare with building without floating column in X-direction and Y-direction respectively.

5.2. Storey Drift

The lateral movement of a floor with respect to the floor below is known as storey drift. Here the Storey Drift of both models are shown in Fig. 5.2. Lateral load is considered to design of both models. The result shown for earthquake load RSX & RSY. According to IS 1893-2016 permissible storey drift ratio should not exceed 0.004 times the storey height as per is code 1893-2016 clause 7.11.



Storey	With Floating column		Without Floating column	
	RSx	RSy	RSx	RSy
1	0.000581	0.000676	0.000531	0.000607
2	0.001655	0.001946	0.001529	0.00175
3	0.001451	0.001648	0.001319	0.001509
4	0.001286	0.001421	0.001211	0.001388
5	0.001195	0.001304	0.001113	0.001281
6	0.001097	0.001175	0.001003	0.001162
7	0.00098	0.001022	0.000873	0.001019
8	0.000827	0.000828	0.000706	0.000833
9	0.000608	0.000559	0.000472	0.000566
10	0.000422	0.000339	0.000273	0.000342

Fig. 5.2. Storey Drift

Table 5.2. Storey drift observation



- As per above graph it is observed that storey drift is maximum for second storey in both the model for the load cases RSx and RSy.
- Maximum story drift of building with Floating Column is 8.2% and 11.2% more in comparison to building Without Floating Column in X-direction and Y- direction respectively.

5.3. Storey shear

Here the storey shear result of both the model are shown in below fig. Lateral load is considered to design of both models. The result shown for earthquake load cases RSx and RSy in the dynamic analysis.

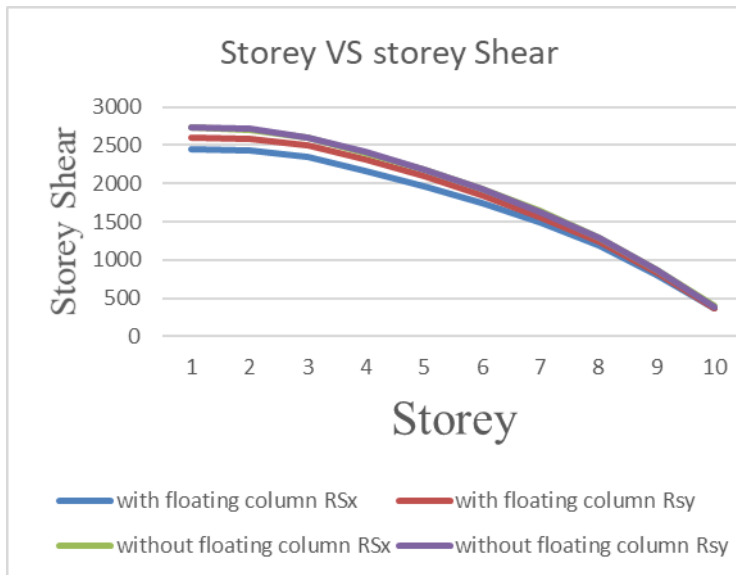


Fig. 5.3. Storey Shear

Storey	With Floating column		Without Floating column	
	RSx (KN)	RSy (KN)	RSx (KN)	RSy (KN)
1	2445.011	2598.993	2726.558	2729.35
2	2429.701	2583.722	2706.931	2709.7
3	2344.716	2498.856	2599.733	2602.105
4	2158.893	2308.64	2405.164	2407.453
5	1956.268	2089.389	2179.111	2180.712
6	1736.222	1844.705	1925.891	1926.246
7	1485.553	1565.977	1636.604	1635.28
8	1184.048	1233.991	1291.027	1288.041
9	810.429	839.184	880.091	876.334
10	362.302	375.794	395.630	393.050

Table 5.3. Storey shear observation

- As per above graph, it is observed that with increasing structural height, storey shear decreases for RSx and RSy load cases respectively.
- Maximum storey shear is observed at the base storey and building without floating column shows 11.5% and 5.01% more as compared with building with floating column in X and Y-direction respectively.

5.4. Storey stiffness

Here the storey stiffness result of both the model are shown in below fig. Lateral load is considered to design of both models. The result shown for earthquake load cases RSx and RSy in the dynamic analysis.

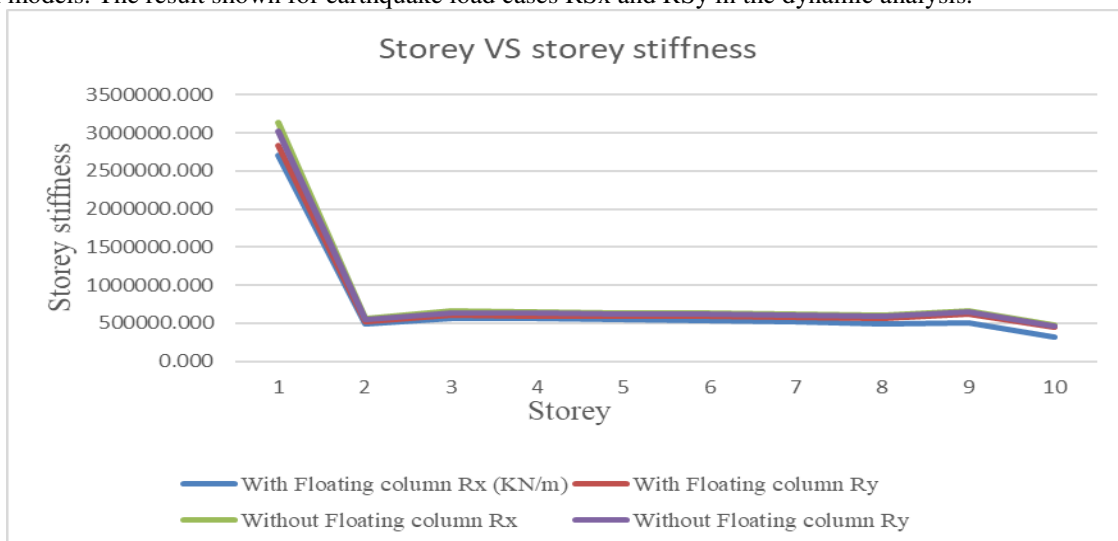


Fig. 5.4. Storey stiffness



Storey	With Floating column		Without Floating column	
	RSx (KN/m)	RSy (KN/m)	RSx (KN/m)	RSy (KN/m)
1	2703248.802	2835189.432	3140761.675	3024490.097
2	490709.912	516819.510	567655.073	547278.027
3	559894.981	608923.404	657355.195	639551.632
4	559605.733	596698.931	648583.612	631696.309
5	548338.574	591770.163	638844.128	622188.487
6	534474.612	584026.462	629623.068	612868.756
7	518061.024	575950.217	620555.031	603437.447
8	495440.799	567103.715	611041.203	593236.512
9	498544.637	614147.336	662884.482	643151.36
10	315969.668	441159.112	482365.578	464946.305

Table 5.4. Storey stiffness observation

- As per above graph, it is found that the stiffness of the storey is maximum at storey 1 in X and y direction for both RSx and RSy respectively.
- Maximum storey stiffness of building without Floating column is 16.18% and 6.67% more as compare to building with Floating column in X and Y-direction respectively.

5.4.1. Stiffness Irregularity check

A storey is said to be soft storey if the lateral stiffness is less than 80% of the average lateral stiffness of the three story above and less than 70% of that in the story above irregularity. A story is said to be extremely soft if its lateral stiffness is less than 70% of the average lateral stiffness of the three story above and less than 60% of that in the story above irregularity.

Storey	Stiffness X-direction	K/Ki+1 (< 0.7)	Check	K(avg)= (k1+k2+k3)/3	K/K(avg) (<0.8)	Check
Story10	315969.668	0				
Story9	498544.637	1.578	Regular			
Story8	495440.799	0.994	Regular			
Story7	518061.024	1.046	Regular	436651.7013	1.18644	regular
Story6	534474.612	1.032	Regular	504015.4867	1.060433	regular
Story5	548338.574	1.026	Regular	515992.145	1.062688	regular
Story4	559605.733	1.021	Regular	533624.7367	1.048688	regular
Story3	559894.981	1.001	Regular	547472.973	1.02269	regular
Story2	490709.912	0.876	Regular	555946.4293	0.882657	regular
Story1	2703248.8	5.509	Regular	536736.8753	5.036451	regular
Storey	Stiffness Y-direction	K/Ki+1 (< 0.7)	Check	K(avg)= (k1+k2+k3)/3	K/K(avg) (<0.8)	Check
Story10	441159.112					
Story9	614147.336	1.392	Regular			
Story8	567103.715	0.923	Regular			
Story7	575950.217	1.016	Regular	540803.388	1.065	regular
Story6	584026.462	1.014	Regular	585733.756	0.997	regular
Story5	591770.163	1.013	Regular	575693.465	1.028	regular
Story4	596698.931	1.008	Regular	583915.614	1.022	regular



Story3	608923.404	1.020	Regular	590831.852	1.031	regular
Story2	516819.51	0.849	Regular	599130.833	0.863	regular
Story1	2835189.43	5.486	Regular	574147.282	4.938	regular

5.5. Torsion Regularity

Here the Torsion of both models are shown in Fig. Lateral load is considered to design of all models. The result shown for seismic loads RSx and RSY.

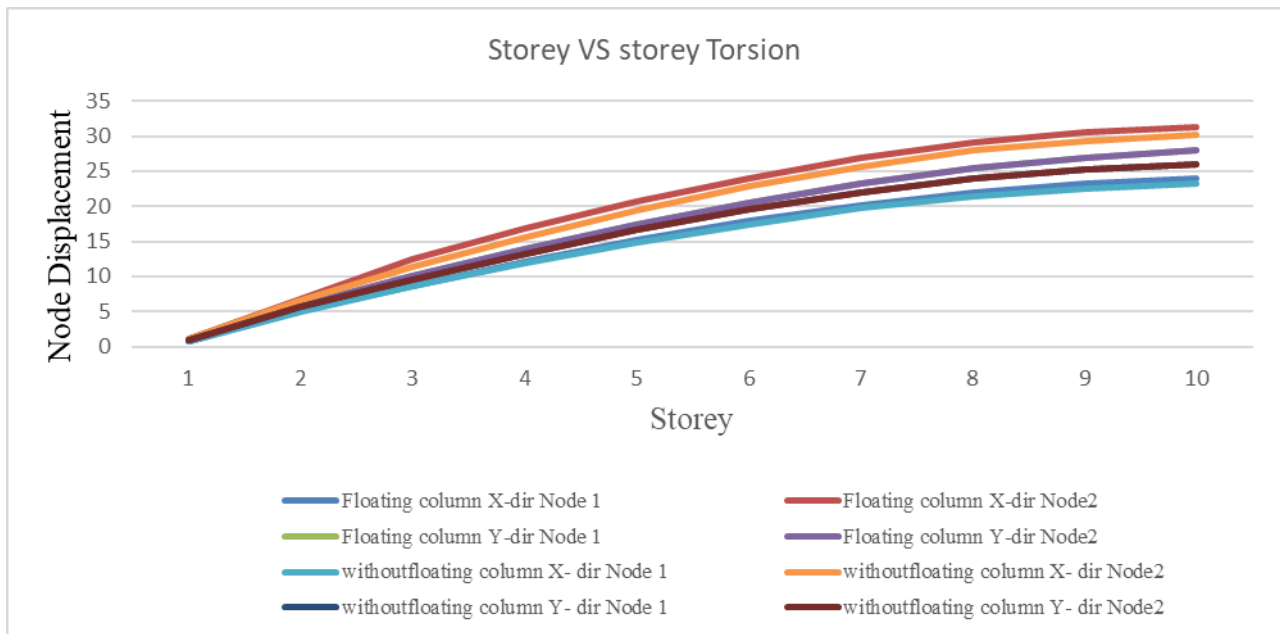


Fig. 5.5. Torsion

Storey	With Floating Column				Without Floating Column			
	X-direction		Y-direction		X-direction		Y-direction	
	Dis. at Node 1	Dis. at Node2	Dis. at Node 1	Dis. at Node2	Dis. at Node 1	Dis. at Node2	Dis. at Node 1	Dis. at Node2
1	0.784	1.049	0.904	0.904	0.776	1.029	0.87	0.87
2	5.073	6.763	5.856	5.856	5.02	6.686	5.634	5.634
3	8.65	12.474	10.037	10.037	8.544	11.287	9.586	9.586
4	12.049	16.8	13.856	13.856	11.835	15.558	13.266	13.266
5	15.152	20.665	17.34	17.34	14.833	19.431	16.609	16.609
6	17.895	24.05	20.458	20.458	17.478	22.837	19.553	19.553
7	20.217	26.892	23.163	23.163	19.714	25.707	22.038	22.038
8	22.05	29.109	25.387	25.387	21.473	27.955	23.987	23.987
9	23.196	30.473	26.9	26.9	22.565	29.344	25.196	25.196
10	23.922	31.317	27.984	27.984	23.251	30.204	25.944	25.944

Table 5.5. Torsion observation

•As per above graph it has been concluded that the Torsion moment increases with increase height of structure in X & Y direction for RSX & RSY load cases respectively.



• From above graph it is observed that the displacement of structure with floating column shows 2.88% at node 1 and 3.68% at node 2 more as compared to building without floating column in X-direction. Also, the displacement of structure with floating column shows 7.86% at node 1 and node 2 more in comparison to building without floating column in Y-direction.

5.5.1. Torsion irregularity check

When the max. horizontal displacement of any floor in the direction of lateral force at one end of the floor is greater than 1.5 times its minimum horizontal displacement in that direction at the other end of the same floor, the building is said to be torsional irregular as per is code 1893-2016 clause 7.1.

Story	With Floating column					
	X- direction			Y- direction		
	Dis. at node 1	Dis. at node 2	Ratio 2/1 (less than 1.5)	Dis. at node 1	Dis. at node 2	Ratio 2/1 (less than 1.5)
10	23.922	31.317	1.309	27.984	27.984	1
9	23.196	30.473	1.314	26.9	26.9	1
8	22.05	29.109	1.320	25.387	25.387	1
7	20.217	26.892	1.330	23.163	23.163	1
6	17.895	24.05	1.344	20.458	20.458	1
5	15.152	20.665	1.364	17.34	17.34	1
4	12.049	16.8	1.394	13.856	13.856	1
3	8.65	12.474	1.442	10.037	10.037	1
2	5.073	6.763	1.333	5.856	5.856	1
1	0.784	1.049	1.338	0.904	0.904	1

Story	Without Floating column					
	X- direction			Y- direction		
	Dis. at node 1	Dis. at node 2	Ratio 2/1 (less than 1.5)	Dis. at node 1	Dis. at node 2	Ratio 2/1 (less than 1.5)
10	23.251	30.204	1.299	25.944	25.944	1
9	22.565	29.344	1.300	25.196	25.196	1
8	21.473	27.955	1.302	23.987	23.987	1
7	19.714	25.707	1.304	22.038	22.038	1
6	17.478	22.837	1.307	19.553	19.553	1
5	14.833	19.431	1.310	16.609	16.609	1
4	11.835	15.558	1.315	13.266	13.266	1
3	8.544	11.287	1.321	9.586	9.586	1
2	5.02	6.686	1.332	5.634	5.634	1
1	0.776	1.029	1.326	0.87	0.87	1

5.6.Modal shape

The relative displacement of all the member of a structure for a certain mode is represented by a mode shape, which is a deflection pattern associated with a specific natural frequency. Different mode shapes will be associated with different frequencies.



The modal shape of both the model and mass participation ratio of the structure for the particular mode is shown below.

Case	Mode	Floating column		Without Floating Column	
		Mode period	Mass Participation Ratio	Mode period	Mass Participation Ratio
Modal	1	1.266	0.855(Along X-dir.)	1.165	0.85 (Along X-dir.)
Modal	2	1.189	0.6971 (Along Y-dir.)	1.165	0..78 (Along Y-dir.)
Modal	3	1.102	0.6982 (Rotation along Z-axis)	1.079	0.7863 (Rotation along Z-axis)

Table 5.6. Mode shape

- After observing the table 5.6., it is found that the first two mode of the building have shown translation in X-direction and Y-direction respectively and the third mode has shown Torsion along Z-axis. This shows the displacement patterns of the structure.

VI. CONCLUSION

- Maximum storey displacement of building with floating column is 7.8% and 3.7% more as compare with building without floating column in X and Y-direction respectively.
- Maximum story drift of building is at storey 2 and building with Floating Column is 8.2% and 11.2% is more as compare with building Without Floating Column in X and Y- direction respectively.
- Maximum shear of the storey is observed at the base storey and building without floating column shows 11.5% and 5.01% more as compared with building with floating column in X and Y-direction respectively.
- Maximum storey stiffness of building without Floating column is 16.18% and 6.67% more in comparison to building with Floating column in X and Y-direction respectively.
- It is observed that the displacement of structure with floating column shows 2.88% at node 1 and 3.68% at node 2 more as compared to building without floating column in X-direction. Also, the displacement of structure with floating column shows 7.86% at node 1 and node 2 more in comparison to building without floating column in Y-direction.
- The model shape of both building shows translation at mode 1 and mode 2 and rotation at mode 3 and natural time period of floating column building has higher magnitude in comparison to without **FLOATING** column building.

VII. SCOPE OF FUTURE WORK

1. Response Spectrum analysis method, as per IS 1893-2016, is used in the present study to assess the seismic performance of soft story RC buildings with and without Floating Columns.
2. Further study can be conducted by Pushover and Time History analysis method.
3. Further study can also be conducted by providing different types of bracing system such as X-bracing, V-bracing, K-bracing and Inverted K-bracing systems.
4. Structure can also be analysed by considering different seismic zones.
5. Studies can be carried out by providing different types of Base Isolators like elastomeric bearing, sliding isolation bearing and Lead Rubber bearing.

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